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(54) Piezo-electrical micropump.

(57) The invention relates to a micropump (1) comprising at least two valves (10,12) and at least one displacing member (11), said valves and said displacing member being piezo-electrically controllable.

A prior art pump of that type is based on a known principle, namely the use of an inlet-valve and an outlet-valve to be opened and closed selectively, and a displacing member. The valves as well as the displacing member are in the form of so-called bimorphs or monomorphs positioned on an e.g. metal diaphragm, i.e. piezo-electrically controllable elements.

The invention has amongst other for its purpose to provide the possibility to make a micropump in fully integrated form.

In order to realize the above objectives the invention first of all provides a micropump of the type mentioned in the preamble, according to the invention being characterized in that the valves (10,12) and the displacing member (11) are the same in form, connected in series in a channel (3,8,9) and being functionally controllable for obtaining a peristaltical displacing of the fluid to be pumped through said channel.

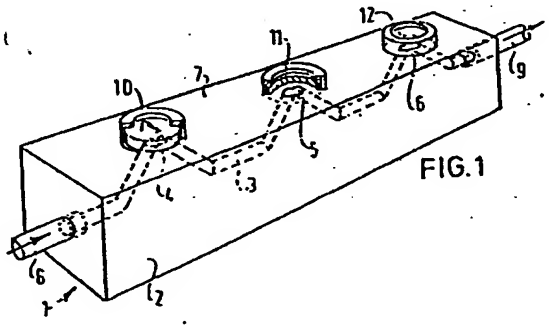

FIG.1

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Besides special precautions has to be taken in order to make sure that the valves present in the fluid are electrically insulated.

In general the invention has as its object to solve the disadvantages of the prior art.

The invention has for its purpose to provide a micropump of a type such that it can be manufactured by using techniques suitable for mass production.

Furthermore the invention has as its purpose to provide a micropump of a type that can be manufactured in an easy way, so that it is cheap.

It is a further purpose of the invention to provide a micropump of a type offering an exact dosing with an improved pressure-independance.

It is an other purpose of the invention to provide a micropump of a type that is well suited for miniaturization. This may be particularly important for pumps to be implanted, e.g. for the dosed dispensing of insulin to diabetics.

Invention has also for its purpose to provide the possibility to make a micropump in fully integrated form. In this connection one can also think of integrating with the pump of a control circuit by using e.g. a well-known silicon-technology.

In order to realize the above objectives the invention first of all provides a micropump of the type mentioned in the preamble, according to the invention being characterized in that the valves and the displacing member are the same in form, connected in series in a channel and being functionally controllable for obtaining a peristaltical displacing of the fluid to be pumped through said channel.

Particularly such a pump can have the special feature that the micropump substantially consists from a bloc having a channel opening out with separated openings at a surface for interruption at the position of each displacing member/valve.

Particularly an alternative embodiment may be used of which the channel consists of separated parts, each opening out in the surface of said bloc with th ir ends and

the total free radius of the carrying chip is valid. It will be obvious that this factor will generally have an other value for the combination carrying chip/piezo-electrical chip.

In order to ensure a long life-time of the pump and to guarantee that the fluid to be pumped is not polluted by material of the pump, preferably use is made of an alternative embodiment, in which all surfaces contacting with fluid to be pumped are chemically inert. Potential-carrying parts being in contact with fluid to be pumped are preferably electrically insulated from that fluid. Using silicon as basis material the related surfaces may be provided with a nitride or oxide layer.

The invention will now be more fully explained with reference to the drawing of some embodiments. In the drawing show:

Fig. 1 a first embodiment of a pump according to the invention in a perspective view partly broken away;

Fig. 2 a perspective view of an alternative embodiment of the pump according to fig. 1;

Fig. 3 partly a cross section and partly a perspective view of a part of a pump according to the invention;

Fig. 4 a cross section through a valve/displacing member for the explanation of the operation thereof;

Fig. 5 a perspective view partly broken away of a further embodiment;

Fig. 6 partly a cross section and partly a perspective view of a part of a further embodiment; and

Fig. 7 a schematic plan view of a fully integrated pump according to the invention.

Fig. 1 shows a pump 1. This pump comprises a bloc 2 in which a channel 3 is present opening out at the upper surface 7 at three positions 4, 5, 6. The channel is connected with aninlet conduit 8 and an outlet conduit 9.

At the positions 4, 5, 6 there are piezo-electrical elements 10, 11, 12. These elements are chip- or disc-shaped, they are sealingly coupled with the upper surface 7 and they can be moved by means of not-shown means

surface 24 adhered by anodical bonding to th upper surface 25 of the silicon chip 17. Between the glass support 15 and the silicon chip 17 an inlet chann l part 26 and an outlet channel part 27 extend. The inl t channel part 26 is connected with an annular recess 28 in the silicon chip 17. An outlet opening 29 is placed in concentrical relation therewith and is connected with the outlet channel part 27. It should be noted that the pump can also be operative in the opposite direction by choice of another type of control. In that case the inlet channel part and the outlet channel part interchange their functions. It will, after the explanation with reference to fig. 1, be clear that the inlet channel part 26 may be connected with an inlet conduit or an outlet channel part of a previous, identical element. Also the outlet channel part may open out at an outlet conduit or an inlet channel part of a next following, identical element.

Fig. 4 shows a cross section of the glass diaphragm 18 that over the annular surface 24 is rigidly fixed to the silicon chip 17.

As can clearly be seen in this figure, by applying a voltage between the connections 22 and 23, and thus the application of an electrical field between the electrodes 20 and 21 the piezo-electrical chip can be caused to take a wave-shape together with the glass diaphragm. This wave-shape is caused by the circumstance that due to the applied electrical field the piezo-electrical chip 19 is subjected to an increase of its diameter (application of an opposite electrical field a decrease of its diameter), which, however, is counteracted by the adhesion to the glass diaphragm 18. Due to this wafer-structure the tendency to the increase of diameter can only result in a wave-shape.

In fig. 4 it can further clearly be seen that, in the direction from the annular surface 24 to the centre of the diaphragm 18 firstly the curvature is directed outwardly, and subsequently inwardly. The transition from the outwardly directed curvature to the inwardly direct d curvature is a bending point, e.g. in the two-dimensional

with ten pumping elements 43 of the type shown in fig. 6. The integrated circuits 37 are by means of bundl s conductive strips 44 connected with a common central contr l circuit 45 of the integrated type.

It should be noted that all services contacting with the fluid to be pumped are chemically inert and electrically insulated. With reference to fig. 6 these are particularly the walls of the inlet channel part 26 and the outlet channel part 27, the annular recess 28, the outlet opening 29 and the lower surface of diaphragm 34. As far as the related surfaces are made of glass, they are already chemically inert. As far as the related surfaces form part of a silicon-element they are oxidized during the manufacturing of the pump, in such a way that a hard silicon-dioxide or quartz layer is present, which is chemically fully inert and electrically insulating.

By a suited, specially adapted control it can be obtained that groups of displacing members/valves are driven, in such a way that "plugs" of fluid are being pumped. It will be clear that thereto a larger number of valves/displacing members are necessary than the basis number of three. It is further remarked that in that case a fault in the form of a leaking valve, and even more leaking valves, will not or at most hardly affect the good pumping operation.

It is further remarked that by a configuration, in which a plurality of pumping units are connected in parallel, but connected to one point with their outputs a mixing of fluids to be pumped may be obtained. By a suitable control even the mixing ratio can be adjusted.

In this connection at last the attention is drawn to the fact that the pumping flow can be chosen by suitably manipulating the following parameters determinitive of the control: the repeating frequency, the fase relation of the several voltages controlling the respective displacing members/valves, the control voltages of the valves/displacing members and at last the number of valves controlled in parallel.

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CLAIMS

1. Micropump comprising at least two valves and at least one displacing member, said valves and said displacing member being piezo-electrically controllable characterized in that the valves and the displacing member are the same in form and connected in a series in a channel and being functionally controllable for obtaining a peristaltical displacing of the fluid to be pumped through said channel.

2. Micropump according to claim 1, characterized in that the micropump substantially consists from a bloc having a channel opening out with separated openings at a surface for interruption at the position of each displacing member/valve.

3. Micropump according to anyone of the preceding claims, characterized in that the channel consists of separated parts, each opening out in the surface of said bloc with their ends and being connectable through a displacing member/valve with a previous or next-following channel part, respectively.

4. Micropump according to anyone of the preceding claims, characterized in that the pump comprises a chip provided with the channel, said chip consisting of glass or

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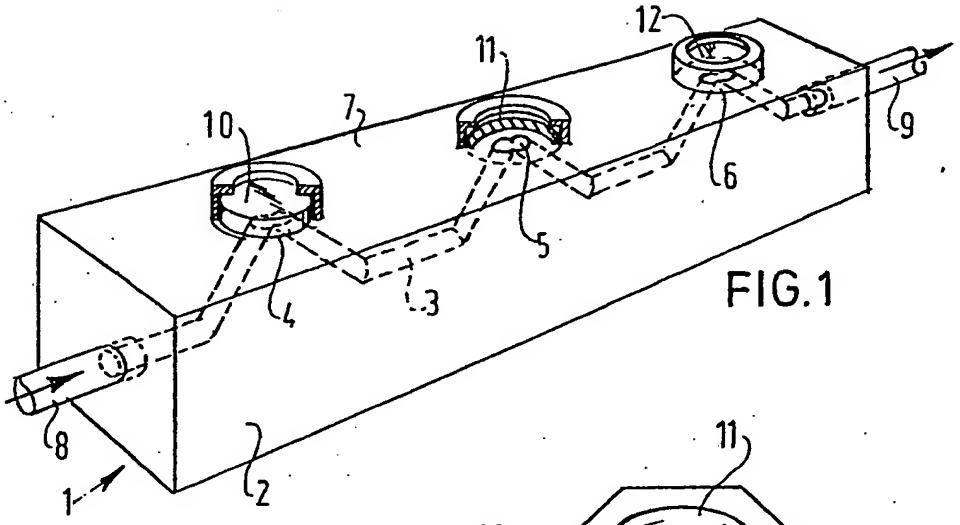


FIG.1

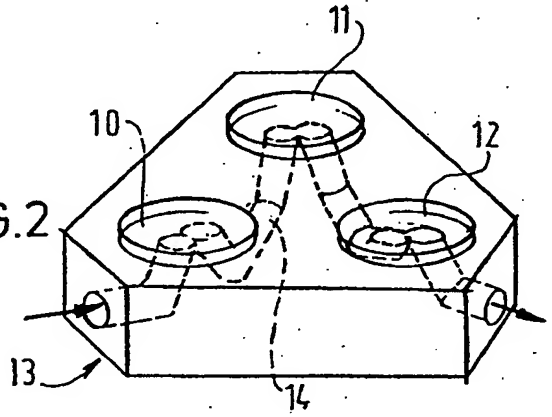
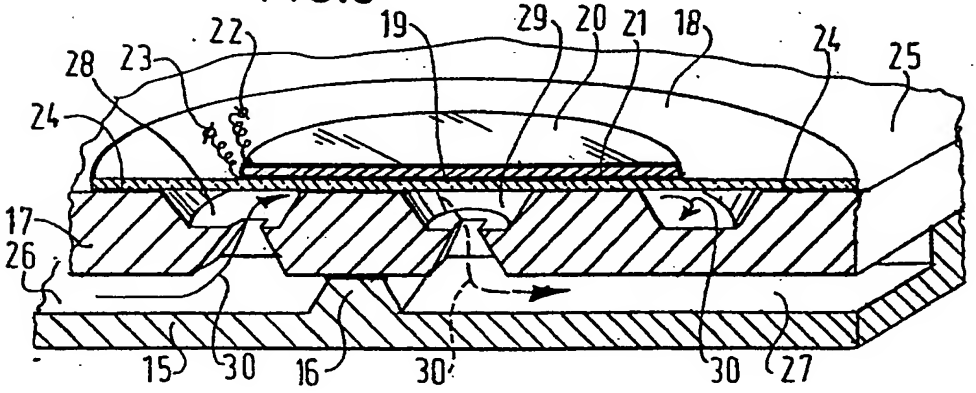


FIG.2

FIG.3



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EUROPEAN SEARCH REPORT

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EP 84 20 1185

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	FR-A-2 379 055 (COMMISSARIAT A L'ENERGIE ATOMIQUE) * Figures 1,2; page 1, line 17 - page 2, line 19; page 4, line 30 - page 5, line 10; page 6, line 30 - page 7, line 15 *	1	F 04 B 43/14 F 04 B 43/00 A 61 M 5/14 G 01 F 11/08 H 01 L 41/08
A		2,3,9	

Y	DE-A-2 354 249 (AB ORIGINAL-ODHNER) * Figures 1-3; page 1, line 1 - page 2, line 5; page 3, paragraph 6 - page 4, line 3 *	1	
A		7	
	---		TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A	GB-A-1 555 814 (BATTELLE MEMORIAL INSTITUTE) * Figures 1,3,6,8; page 1, lines 7-17; page 2, line 56 - page 3, line 5; page 3, lines 31-36; page 4, lines 10-16 *	1-3,6	F 04 B A 61 M H 01 L G 01 F

A	US-A-4 231 287 (PARKER) * Figures 1-9; column 2, line 41 - column 4, line 36 *	7,8	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12-10-1984	VON ARX H.P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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